IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA, ex rel, W. A. DREW EDMONDSON, in his capacity as ATTORNEY GENERAL OF THE STATE OF OKLAHOMA, and OKLAHOMA SECRETARY OF THE ENVIRONMENT C. MILES TOLBERT, in his capacity as the TRUSTEE FOR NATURAL RESOURCES FOR THE STATE OF OKLAHOMA,	§	
Plaintiff,	§	CASE NO. 05-CV-329-GKF-SAJ
V.	§	
TYSON FOODS, TYSON POULTRY, INC., TYSON CHICKEN, INC., COBB-VANTRESS, INC., AVIAGEN, INC., CAL-MAINE FOODS, INC., CAL-MAINE FARMS, INC., CARGILL, INC., CARGILL TURKEY PRODUCTS, LLC, GEORGE'S, INC., GEORGE'S FARMS, INC., PETERSON FARMS, INC., SIMMONS FOODS, INC. AND WILLOWBROOK FOODS, INC.	§	
Defendants.		

EXPERT REPORT OF GORDON V. JOHNSON, Ph.D

1. Introduction

I, Gordon V. Johnson, grew up and lived on a small diversified farm in North Dakota until attending North Dakota State University, where I received a B.S. in agriculture majoring in Soil Science in 1963. I received a M.S. in Soil Science from the University of Nevada (Reno) in 1966 and a Ph. D in Soil Science from the University of Nebraska in 1969. From 1969 to 1977 I taught undergraduate

3. Behavior of Phosphorus in Soils and the Environment.

a. Elemental P does not exist in nature, and is only a phenomenon of the laboratory and industry. White elemental P is a very reactive solid at room temperature and must be stored under water to prevent its reaction with oxygen (O_2). When exposed to the atmosphere it reacts violently with O_2. In nature P exists in combination with oxygen as the oxy-anion, orthophosphate (PO_4^{3-}), which is relatively stable, but bound with cations to form a variety of compounds. When hydrogen (H^+) is the only cation (laboratory situations), phosphate is present in the moderately strong phosphoric acid, H_3PO_4.

b. In soil solutions, PO_4^{3-} will react with whatever cations have the highest charge and are present in highest concentration. A deciding factor in what compound will eventually be formed by reacting with PO_4^{3-}, is the stability of the final compound formed. Thus, because aluminum phosphate ($AlPO_4$) and iron phosphate ($FePO_4$) are extremely stable, they are formed in soils acidic enough to cause aluminum (Al^{3+}) and iron (Fe^{3+}) to dissolve and be present to react with PO_4^{3-}. In soils where the pH is above 5.5 there is enough calcium (Ca^{2+}) present to form calcium phosphates, the least soluble (most stable) being rock phosphate or the mineral apatite ($Ca_5(PO_4)_3OH$). Rock phosphate is mined commercially from geologic marine deposits and is the primary raw material from which commercial fertilizer is manufactured.

c. Whenever fertilizer is added to soils the soluble phosphate will begin to react with calcium present in the soil to form various calcium phosphates of low solubility (plant availability) the final product (after about two years) being rock phosphate. In soils of pH suitable for plant growth (pH 5 to 8), the hydrogen (H^+) concentration in the soil solution is very low (1×10^{-5} to 1×10^{-8} mole/liter). These concentrations allow small amounts of PO_4^{3-} to be present in combination with H^+ in the form of $H_2PO_4^-$ and HPO_4^{2-}, the ionic forms of P taken up by plants.

d. Soils typically contain forms of organic and inorganic P in total amounts ranging from about 200 to 6,000 lb/acre. As plants grow they absorb inorganic water soluble P from the soil. Water soluble P removed by plants is repeatedly replenished by chemical transformation of less soluble forms of P in the soil to water soluble forms as a result of mass-balance, chemical equilibrium reactions.

4. Phosphorus (P) as an essential macronutrient for plants.

a. Phosphorus is one of 16 chemical elements essential for plants to grow and complete their life-cycle. Three of the elements, carbon (C), hydrogen (H) and oxygen (O) are supplied through absorption from air and water. The remaining 13 are absorbed primarily from the soil and are categorically grouped according to their common deficiency in soils, which is also closely related to the amount used by plants. Nitrogen (N), P, and potassium (K) commonly become deficient in intensively cropped soils because plants contain large amounts of these nutrients compared to available soil levels. They are classified as "primary nutrients" or "macronutrients". Less commonly deficient are the "secondary" nutrients calcium (Ca), magnesium (Mg) and sulfur (S). The "micronutrients" iron (Fe), manganese (Mn), copper (Cu) zinc (Zn), boron (B), chlorine (Cl) and molybdenum (Mo) are found in the lowest concentration in plants and are seldom deficient in soils.

b. Plants use much larger amounts of N (1 to 3 %) and K (about 1 %) than P (about 0. 2 to 0.4 %). Phosphorus is absorbed by plants in the form of orthophosphate, an inorganic anion of single ($H_2PO_4^-$) or double charge ($H_2PO_4^{2-}$). A primary function of P within the plant is in energy transfer, as a component of ADP (adenosine di-phosphate) and ATP (adenosine tri-phosphate), and it is easily transferred from old tissue to new tissue when soil supplies are deficient. Deficient leaves become discolored, and appear chlorotic (yellow) and often purple.

5. Nutrient Management.

a. The management of nutrients for agronomic production developed as farmers and soil scientists observed that crop yield could be maintained in intensively cropped fields with the addition of fertilizer. Early in American agriculture fertilizer materials included animal manure, rock phosphate, wood ashes, and various forms of mined nitrates. The amounts of these materials applied to a given field depended upon the cost and availability of the materials. Use of these fertilizers was also influenced by the anticipated increase in crop yields. Early research led to the common understanding that crops most often responded to soil inputs of nitrogen (N) phosphorus (P) and potassium (K), although other "secondary" (Ca, Mg, and S) and "micronutrients" (Fe, Zn, Mn, Cu, B, Cl, and Mo) were also essential for plant growth and development. Therefore, interest grew in developing technology that could identify how much N, P, or K should be applied to a field to gain the maximum crop yield at the least cost. The development of soil test procedures for N, P, and K followed.

b. Although most soil P exists in solid form and plants absorb water soluble P, neither soil analysis evaluating water soluble P nor total soil P accurately predicted the soils capacity to provide a crop's P need for maximum crop yield. Instead, chemical extractants were developed that successfully mimicked plant use of P. Using these extractants a relationship was developed between P extraction amounts (soil test P, or "STP") and crop yield. This relationship is called soil test correlation. Finally, the STP results were related to crop yield response from fertilizer P addition through field experiments performed on farmer's fields and at OSU Agricultural Experiment Stations. The result of this work is that the tests are calibrated, and we know that an STP of 65 lb P/acre (ppm times a factor of 2.0 is equivalent to lb/acre) provides a maximum benefit of 100% P sufficiency for efficient forage crop production of bermudagrass and fescue and an STP of 40 provides 95% yield sufficiency for these crops. Because there is no P benefit to crops once the STP is 65 lb/acre or higher, this STP becomes the agronomic critical level (ACL). Bermudagrass and fescue are the predominate forages grown in the IRW.

c. These correlation-calibration P relationships that establish good agronomic use of P as a fertilizer have been published by the Oklahoma State University in OSU Bulletins and "Fact Sheets" that include tables showing the relationship and the need, if any, for additional P as a fertilizer to accomplish maximum crop yield. These publications include a table showing the categorization of soil test results and identify a STP value of 65 as being adequate , i.e., any additional input of P fertilizer would have no agronomic benefit. This calibration was originally published in 1965 and has been verified by field research through time (Baumann, 1965.) The following tables are reproductions of the tables that were first published in the OSU Fact Sheet 2225 (Baker and Tucker, 1973) and are in the current OSU fact sheet widely used for nutrient management and soil test interpretation (Zhang, H., et al., 2006).

7. <u>STP and P management in the IRW.</u>

a. I have evaluated available information to determine if I can form an opinion on the agronomic P needs in the Illinois River Watershed using the STP correlations and calibrations discussed above. Based on the 2002 Census of Agriculture, 92.3 % of the total cropland is forage production (pasture or hay) for the counties within which the IRW resides in Oklahoma and Arkansas (2002 Census of Agriculture). Fescue and bermudagrass are the primary forages used for pasture and hay production. For these crops an STP value of 65 produces the maximum crop yield. Therefore, application of P to fields where soils are at or above an STP of 65 is not an agronomically reasonable practice. If the STP levels in IRW soils reach this maximum agronomic level, then those soils would not reasonably require additional P inputs from poultry litter.

b. I have reviewed the STP results from a Court supervised, land application of litter project in the Eucha-Spavinaw watershed in Eastern Oklahoma and Western Arkansas for 2006 and 2007. These soil tests were performed as a prerequisite to land application of poultry litter on managed for pasture and hay production. Integrators, identified in the database provided by the manager are Peterson Farms, Simmons, Tyson, Cobb-Vantress, Georges, Cargill, and Moark (see Excel data files). The test results would be typical for fields where poultry litter application occurs in Oklahoma and Arkansas. As such, they reflect STP for pasture soils in the IRW because of the similarity of land use, poultry operation and soil types in these contiguous watersheds. Of 617 observations in Arkansas, 601 (97%) had STP values in excess of 65 lb/acre and only 5 (< 1%) had values less than 40. The average STP (290 lb P/acre)for Arkansas samples was more than four times the agronomically reasonable STP of 65. For the 678 samples from Oklahoma the average STP was 165, 81 % had STP values greater than 65 and 91 % of the samples were greater than 40. The average STP was 2.5 times the agronomically reasonable STP of 65 (Figure 3). The sampling depth was set at 4 inches by the court and thus the calculated lb/acre STP is likely less than it would be for a 6-inch depth.